# Knowledge Representation for High Quality Learning

Salim Lardjane, Anna Maaria Nuutinen


# Knowledge Representation for High Quality Learning

**Salim Lardjane[1], Anna Maaria Nuutinen[2]**

## 1. Introduction : Future-based learning

Future-based learning aims at bringing education 'out of the box' based on predictions of future trends and requirements in the labor market and society.

One of such trends appears to be the march towards a more sustainable development of society and industry. Other trends seem to be the emergence of the so-called Learning Society and Knowledge-based Economy.

Future-based learning involves a holistic, integrated approach to education. It is a bridge between the current state of our schools and what they may become in the future.

Different kinds of stakeholders, originating from society and the professional world must be involved in order to answer the growing need of the economy, in sectors that will drive future developments. Schools are embedded in environments that provide

[1] Université de Bretagne-Sud, Laboratoire de Mathématiques de Bretagne Atlantique, CNRS UMR 6205, France, http://web.univ-ubs.fr/lmam/
[2] City of Espoo, Educational and Cultural Services, PL 1, 02070 Espoon Kaupunki, Finland, http://www.espoo.fi/rce

sources of knowledge and experience and should take full advantage of these environments. In particular, Industry should be become a full educational partner.

Future-based learning brings to pupils, teachers and staff direct learning interactions with the changing outside world.

It should involve a qualitative upgrade of content and of skills towards more applicable and scientific knowledge.

Enquiry-based, problem-based and work-based learning requires a further professionalization of teachers. There should be a continuous high level process of professionalization in order to have the teacher meet the youngsters' need and address the quality of education required by the world of work.

Schools have to be more open and more focused on innovation. They should become an open focal point or nexus in the lifelong learning process of individuals. The gap between basic, secondary and higher education should be bridged by an uninterrupted process of development, optimizing the individuals' discovery of their own talents and potential, and reducing the consequences of early school leaving. Innovation must become a part of education in a structured way, no longer as a temporary endeavor.

Education should become a joint cause and course for the young. Youngsters should be invited to learn, challenged to 'go out' and experience. They should be challenged to act as entrepreneurs of their future. Textbooks should be a mere guidance.

Future-based learning aims at transforming the school. It is a process of educational transition.

The OPEDUCA project is a step in this direction.

# 2. Knowledge Representation Tools

## 2.1. An overview of some knowledge representation tools

The common aim of graphical knowledge representation techniques in Education is to promote a *deep approach* to Learning.

There is empirical evidence that the use of graphical knowledge representation tools enhances learning and improves knowledge – when people are able to represent a complex set of relationships as a diagram, they are more likely to understand and remember them.

The principle of *dual coding* underlies the functioning of most graphical knowledge representation tools – in a mind maps, for instance, information is coded in visual as well as propositional form.

Although the objectives of all graphical knowledge representation techniques are similar, there are differences in their conception and use.

*Mind mapping* allows people to imagine and explore associations between concepts or ideas.

*Concept mapping* allows people to understand the relationships between concepts and hence understand these concepts.

*Argument mapping* allows people to represent inferential connections between propositions and to evaluate them in terms of validity of argument structure.

A mind map consists in a network of connected and related concepts. Spontaneous thinking is required when drawing a mind map and the aim of mind mapping is to develop creative associations between ideas.

*Concept mapping* is often confused with mind mapping. It is however more structured and less pictorial. The aim of concept mapping is not to develop spontaneous associations between ideas but to outline the relationships between these ideas. Thus, concept mapping is a relational tool.

*Argument mapping* is a recent innovation and is generally computer-aided. It has a different foundation than mind and concept mapping. It puts the emphasis on the inferential structure of arguments or statements.

The main components of mind maps are images and topics, those of concept maps are concepts and relations, while argument maps summarize inferences between whole propositions.

### 2.2. Knowledge Representation Tools and Levels of Abstraction

On usually distinguishes three levels of abstraction in our knowledge about the objects of the real world:

1. *The conceptual level*

This is the highest level of abstraction. At the conceptual level, objects are considered from an external point of view. They are abstracted as concepts. Relationships between objects translate into associations between concepts. Information is summarized through a conceptual model.

2. *The organizational level*

At this level, objects are abstracted as systems of simple concepts. Their internal structure is the focus of interest. Information is summarized through a relational model.

3. *The logical level*

At this level, objects are abstracted as pieces of information. The relational model disappears and relationships are understood as logical objects in their own rights. Information can be summarized through tables.

We propose that different mapping tools correspond to different levels of abstraction.

Mind maps correspond to the *conceptual* level.
Concept maps correspond to the *organizational* level.
Argument maps correspond to the *logical* level.

### 2.3. Knowledge Representation Tools and Information Gathering

Due to the emergence of the global Knowledge Society, educational systems are increasingly open to other socio-economic actors and to the media. Several initiatives, among which OPEDUCA, accompany this trend by developing and promoting new teaching concepts and methodologies.

Pupils are increasingly gathering valuable information from a variety of sources like the internet, television, magazines and movies, but also through interactions with professionals whom they visit, or who visit their schools.

In such a dynamical information-laden context, tools are needed to assimilate and organize information on the go.

Concept maps and mind maps, for instance, can be such tools. They allow pupils to integrate information gradually and visualize the progress of their *own* learning and understanding.

Concept maps or mind maps can be drawn all along a learning path, testifying to the growing knowledge of a pupil, or of a group of pupils if they are created collaboratively.

New concepts and links or branches appear gradually in the map, others may disappear. The dynamic graphical representation thus parallels the dynamic learning process of the pupils.

Modern graphical knowledge representation software allows this dynamical aspect to be taken into account – a tool like cMap allows one to record short movies showing the evolution of a concept map through time.

# 3. Mind Maps

## 3.1. What is a Mind Map?

The human brain does not work as a computer but in a natural, organic way.

Mind maps are a *visual mental tool* reflecting the natural organization of the brain. They allow one to think laterally (bi-dimensional thinking) instead of thinking linearly (one-dimensional thinking).

They can be applied to all the functions of the brain, in particular to *Memory*, *Creation* and *Learning*.

They were introduced by Tony Buzan in the 1970s.

Ideally, a mind map is structured in the following way:

At the center of the mind map, an image summarizes the main subject of the map. Branches are then drawn starting from the central image: The first branches represent the main themes associated with the main subject. Secondary branches correspond to secondary themes. An image and/or a keyword appear on each branch.

*The more beautiful a mind map, the more efficient it is. The more creative the mind mapping process, the more successful the mind map is.*

## 3.2. Five Steps To Mind Mapping

Here are five steps that can be followed to create a Mind Map.

1. *Create a central idea*

The central idea is the starting point of the Mind Map and represents the topic one is going to explore. It usually includes an image that represents the Mind Map's topic.

2. *Add branches*

The next step is to add branches. The main branches which flow from the central image are the key themes. One can explore each key theme in greater depth by adding secondary branches, and so on.

3. *Add Keywords*

Each new branch of the Mind Map must correspond to an idea or concept. An important principle of Mind Mapping is using one word per branch.

4. *Color code the branches*

Color coding links the visual with the logical and helps the brain to create mental shortcuts. The color code allows categorizing, highlighting, and analyzing information.

5. *Include Images*

Images have the power to convey much more information than a word or sentence. They are processed instantly by the brain and are a universal language which can overcome any language barrier.

### 3.3. Why Do Mind Maps Work?

The most important reason for the increased use of mind maps is that they enhance people's learning.

But why do mind maps work?

Several reasons have been advanced to explain it, among which:

1. *Mind maps support meaningful learning*

This means that, thanks to mind maps, new perspectives are integrated into people's knowledge.

2. *Mind maps build on existing knowledge*

This is due to the fact that mind maps improve the usability of existing information and complement it with new elements.

3. *Mind maps make new information more usable*

Drawing, studying or manipulating mind maps develops people's skills more than less usable information representational techniques.

4. *Mind maps augment the brain's ability to understand and process information*

This is due to the fact that diagrams are more easily stored in memory than other kind of representational devices.

5. *Mind maps promote active engagement*

This enables people to develop their own learning path and check their own understanding.

### 3.4. Collaborative Mind Mapping

Mind Mapping is often considered as a personal endeavor – drawing a graphical representation of one's own ideas about a main topic.

However, mind maps can, and have also been created and used in a collaborative way.

Here, the emphasis is on interpersonal understanding and common knowledge building.

Collaborative mind mapping can involve a facilitator (a teacher, in an educational setting) and several participants (pupils, in an educational setting).

The creation of collaborative mind maps involves four steps:

1. The **brainstorming** step: Ideas about the main topic are put forward by each participant and laid down on paper or on board by the facilitator.

2. The **organizing** step: Ideas are classified; common concepts are identified and gradually laid down on a separate paper or a separate part of the board.

3. The **relational** step: Concepts are circled and links between concepts are identified and drawn.

At the end of these three steps, the graphical representation which is obtained can be a basis for a mind map or a concept map.

4. The **graphical** step: A mind map or a concept map based on the output of the relational step is drawn by the facilitator interactively with the participants.

## 4. Concept Maps

### 4.1. What is a concept map?

Concept maps are a graphical tool for organizing and representing knowledge.

They include unique concepts, usually enclosed in circles or boxes. Lines and linking words between concepts suggest hierarchical relationships.

They were originally designed to assist people in visualizing the way they organized and structured their thoughts.

They allow one to form meaningful propositions about the map's theme and are very much used in quantitative social research.

### 4.2. The Origins of Concept Mapping

According to Åhlberg (in *Varieties of Concept Mapping*, Proceedings of the First International Conference on Concept Mapping, Spain 2004): "It is commonly known that concept mapping was developed at Cornell University. Stewart, Van Kirk, and Rowell (1979) claim, in The American Biology Teacher, that they developed concept maps. However, in their concept maps, the links were not named and no propositions were formed from concepts. In that same journal, Novak (1979, 1980) later published two articles in which he referred to Stewart, Van Kirk, and Rowell (1979). He also presented examples of concept maps, but the links were still unnamed. However, in Novak (1981) the links were named, and meaningful propositions were created out of concepts. This is the form of Novakian concept maps that has been spread globally. In fact, Novak and Gowin (1984) were very influential in spreading it all over the world".

### 4.3. Five Steps to Concept Mapping

How does one construct a concept map?

Here are five steps to do so.

1. The **brainstorming** Step: Write down the major terms or concepts you know about a given topic on a piece of paper. Then, write each concept or term on a post-it.

2. The **organizing** Step: Sort through the post-its, putting terms you do not understand aside. Also put aside those that are not related to any other term or concept. The post-its left over are the ones that will be used to construct the concept map.

3. The **layout** Step: Stick the post-it's on a piece of paper so that related terms are close to each other. Try to group them so as to emphasize hierarchies. Identify

terms that represent higher categories, write them on post-it, then add them. Feel free to rearrange thing at any time during this phase. The most important concepts or terms should be at the center or at the top.

4. The **linking** Step: Draw lines with arrows between the terms you think are related. Then, write on each line a word or a short sentence describing the relationships between the terms or concepts. Many arrows can originate or terminate on particularly important concepts.

5. The **finalizing** Step: If you put any post-it aside in Step 3, go back and see if some of them will fit into the concept map just constructed. If they do, add the lines and relationships corresponding to the new items. Then, convert the concept map into a *permanent* form by drawing it on a piece of paper or on the computer. Be creative through the use of colors, fonts, shades, border thickness, and so on. Finally, you can give a title to your concept map.

## 6. Analyzing and Synthesizing Mind Maps

### 5.1. Normative Mind Map Analysis

The normative analysis of a mind map consists in comparing it as a whole or branch by branch to a reference map.

For example, in the case of the French synthetic OPEDUCA mind maps (see Appendix), one could compare the *Solutions* branches appearing in the different maps to a reference Solutions branch created by the Analyst or by an Expert.

This reference branch could, for example, span the following sub-branches: *Short-term*, *Middle-term*, *Long-term*, with *Education* appearing as a sub-branch of *Solutions – Long-term*.

This normative analysis can help suggest to the creator or creators of the mind map new associations and ideas about the topic. It can also be used in an assessment process.

### 5.2. Comparative Mind Map Analysis

How can mind maps be compared?

Mind maps provide a graphical representation of the concepts evoked by a topic in someone's mind or in the minds of a group of people if they are created collaboratively.

They are always drawn by an individual: a learner (a pupil, in an educational setting), a facilitator (a teacher) if they are created collaboratively, or an analyst (in synthetic mind mapping – see section 5.3.).

Two kinds of comparisons can be made:

1. *Comparison of mind maps about the same topic*

Here, the analyst starts by comparing the key themes of the mind maps, identifying the key themes which are shared by the different mind maps and the ones which differ.

Then, the analyst singles out the common key themes for which the secondary branches differ most.

The difference between the secondary branches reveals a difference in meaning of the key theme in the different mind maps. This reveals in turn that different associations with the main topic are designated by the same label (key theme) in the different mind maps.

To sum it up, the comparison of several mind maps about the same topic can proceed in the following way:

a. List the key themes which are common to the different mind maps and the ones which differ.
b. For the common key themes, list those who differ in their interpretation based on the secondary branches, and provide this interpretation.

2. *Comparison of mind maps about different topics*

Here, the analyst starts by identifying the concepts which are common to all the minds map and, for each of these concepts, looks at the branch in which they appear and the branches which originate in them.

For example, in the French OPEDUCA synthetic mind maps about Food, Energy, and Water (see Appendix), one can see that the concept of *Costs* is shared by the three mind maps. However:

- For Food, it appears in the branch: *Distribution*
– For Energy, it appears in the branch: *Society*
– For Water, it appears in the branch: *Marketing*

The sub-branches of *Costs* are:

- For Food: *Retail, Transportation, and Politics*
- For Energy: *Checks, Regulations, Strategies, Consumption, Conception, Policies, and Control*
- For Water: *Network, Collectivity, Bills, Service, and Cleansing*

This reveals a *different understanding* of the concept of *Costs* for the three topics. For Food, it is a *distribution* cost, for Energy, it is a *societal* cost, and for Water, it is a *production* cost.

Note that this approach can also be used for mind maps about the *same* topic. However, in this case, the common concepts are likely to be more numerous. So, in order to apply this method, the analyst has to single out one or two concepts on other grounds.

### 5.3. Synthetic Mind Mapping

How is one to synthesize several mind maps about the same topic ?

Such a question may arise in an educational setting when mind maps about the same topic are created by different classes or groups of pupils.

That was for example the case in the "Flight for Knowledge" phase of the OPEDUCA project in France. Four topics were proposed to the pupils: Food, Energy, Water, and Eco-Design. On each of these topics, mind maps were created by different groups of pupils in a collaborative way.

The task of analyzing these mind maps was entrusted to the University of Southern Brittany. It immediately appeared that, besides comparative and normative analyzes of the different mind, a *synthesis* of these maps would be helpful in visualizing the collective knowledge of the pupils about the topics. It could also be submitted back to the pupils as a basis for discussion. This could enhance their knowledge about the topics with concepts originating from other pupils.

The four synthetic mind maps constructed at the University of Southern Brittany appear in the Appendix.

A rigorous procedure has to be followed to derive this kind of synthetic mind maps.

First, a decision about the *depth* of the *synthetic* mind map has to be made. In the case of the former mind maps, this level was often three, extending to four for some particular branches. Here, the depth is understood as the maximum number of sub-branches along a branch. Let us denote this depth by $\Delta$.

Then:

- Gather all the mind maps that deal with the same central topic and put them in a stack.

- Put the central topic at the center of the synthetic mind map.

- Add all the key themes from the first mind map to the synthetic map.

- On the second mind map, cross out all the synthetic map's key themes. Then, add all the remaining key themes to the synthetic map .

- Proceed in the same way with the third mind map, and so on, until you reach the end of the stack.

During this process, for each new mind map from the stack, all the key themes from the synthetic map are crossed out and the remaining themes are added to the synthetic map.

At the end of this procedure, all the key themes of the synthetic mind map are identified.

Proceed in the same way for each key theme. That is:

- Start by identifying the mind maps where the key theme is present.

- Put them in a stack.

- Add the secondary branches of the key theme from the first mind map as secondary branches of the key theme in the synthetic map.

- Cross them out on the second mind map and add the remaining secondary branches to the synthetic map, and so on.

At the end of this process, all the secondary branches of the key theme in the synthetic mind map are identified.

- Iterate this process for all the synthetic map's key themes.

Then, apply the same procedure for each secondary theme, and so on.

A draft of the final synthetic mind map is obtained *when all the concepts with depth lower or equal to Δ have been crossed out on all the original mind maps*.

Finally, edit this draft to obtain your final synthetic mind map, following the general principles of mind mapping.

### 5.4. The Collaborative Use of Synthetic Mind Maps In The Classroom

Teachers are professionals; they have their teaching skills. They have learning objectives for their pupils. But the pupils may know something that the teacher does not know. Everybody is a learner, including the teacher.

In any case, teachers should have a bigger picture about the topic under study. They are more experienced. Their duty is to facilitate the learning process of their pupils.

Presenting synthetic mind maps to the pupils, derived from their own mind maps by the teacher, can be a tool for such an endeavor. They can be a basis for discussion, arouse questions, and contribute to the building of a new common knowledge. Finally, they can help promote good interactions between the pupils, with the teacher, and with other people.

## 6. Conclusion : High Quality Learning and Knowledge Representation Tools

Mind maps and concept maps can be used to promote meaningful high quality learning and teaching.

They show *externally* and *explicitly*, hidden and implicit conceptual and propositional structures. This promotes *shared* understanding, learning, thinking and acting and hence contributes to *high quality learning* (Åhlberg 2013).

Mind maps and concept maps can also facilitate *meta-learning*.

Meta-learning (*metacognitive* learning) is learning about one's own learning, thinking and acting. Learning about one's own best learning styles and learning to be a more self-directed learner are two important aspects of meta-learning. Both contribute to high quality learning and are promoted by mind maps and concept maps (Novak, Gowin 1984).

Thus, knowledge representation tools are keys to fruitful thinking and discussion, *for* and *about* learning. They are very appropriate learning tools for a high-quality *open* education.

## References


[1] Åhlberg, M. K. (2004) *Varieties of Concept Mapping*, Proc. First Int. Conference on Concept Mapping, Pamplona, Spain.

[2] Åhlberg, M. K. (2013) *Concept mapping as an empowering method to promote learning, thinking, teaching and research*. Journal for Educators, Teachers and Trainers, Vol. 4 (1), pp. 25-35.

[3] Buzan, T. (2005) *The Ultimate Book of Mind Maps*, Thorsons.

[4] Buzan, T. (2005) *Mind Map Handbook*, Thorsons.

[5] Buzan, T. & Buzan, B. (2010) *Mind map : Dessine-moi l'intelligence*, Eyrolles/BBC.

[6] Buzan, T. & Griffiths, C. (2011) *Le mind mapping au service du manager*, Eyrolles.

[7] C.R.D.P. de Toulouse (2013) *Usages pédagogiques des cartes mentales.*

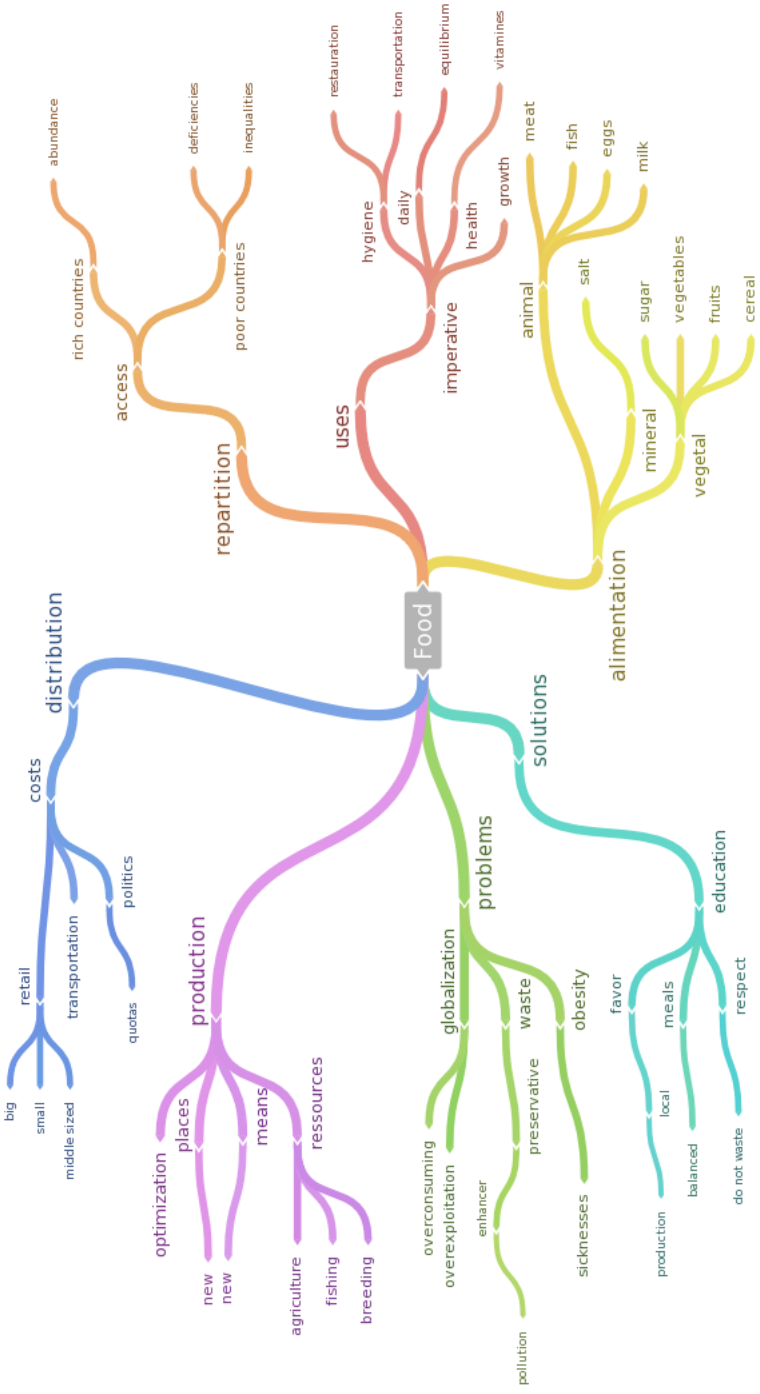
[8] Deladrière, J. L., Le Bihan, F., Mongin, P. & Rebau, D. (2007) *Organisez vos idées avec le Mind Mapping*, Dunod.

[9] Novak, J. D. & Gowin, D. B. (1984) *Learning How to Learn*, Cambridge.

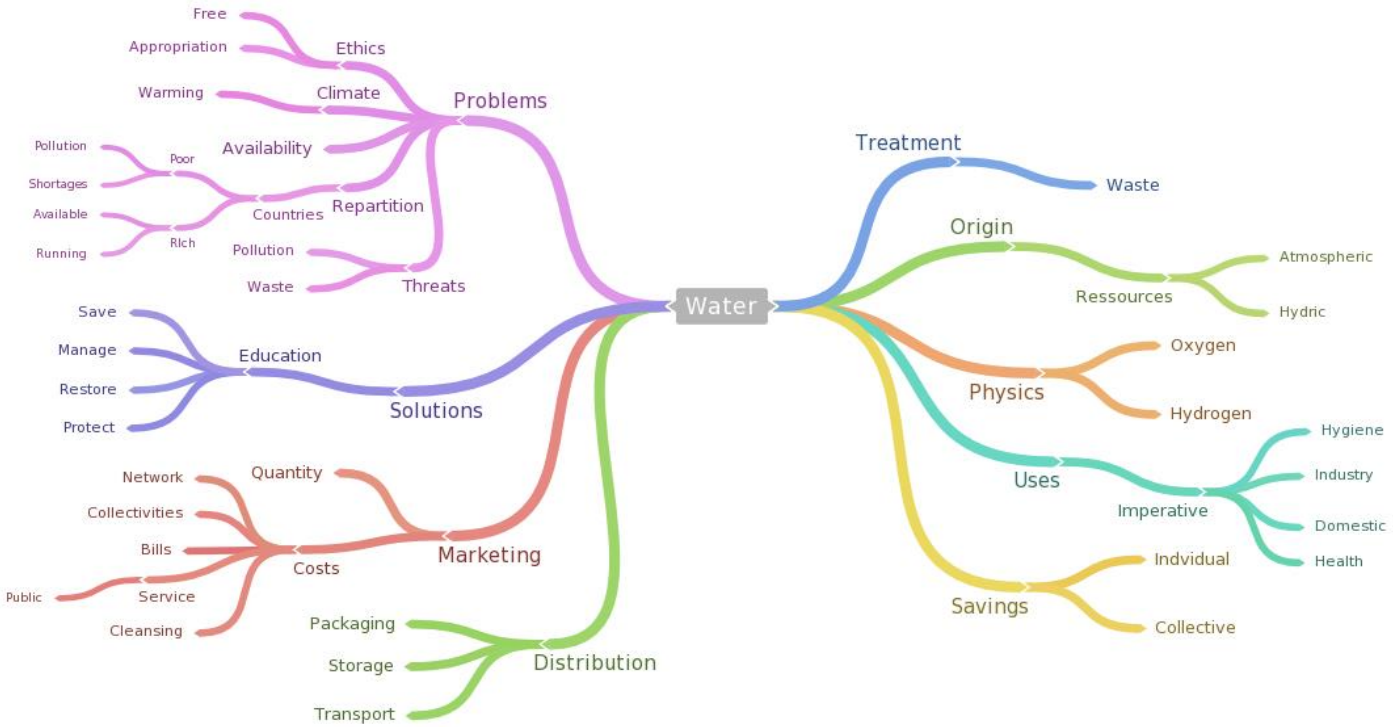
[10] Wheeldon, J. & Ahlberg, M. K. (2012) *Visualizing Social Science Research*, Sage.

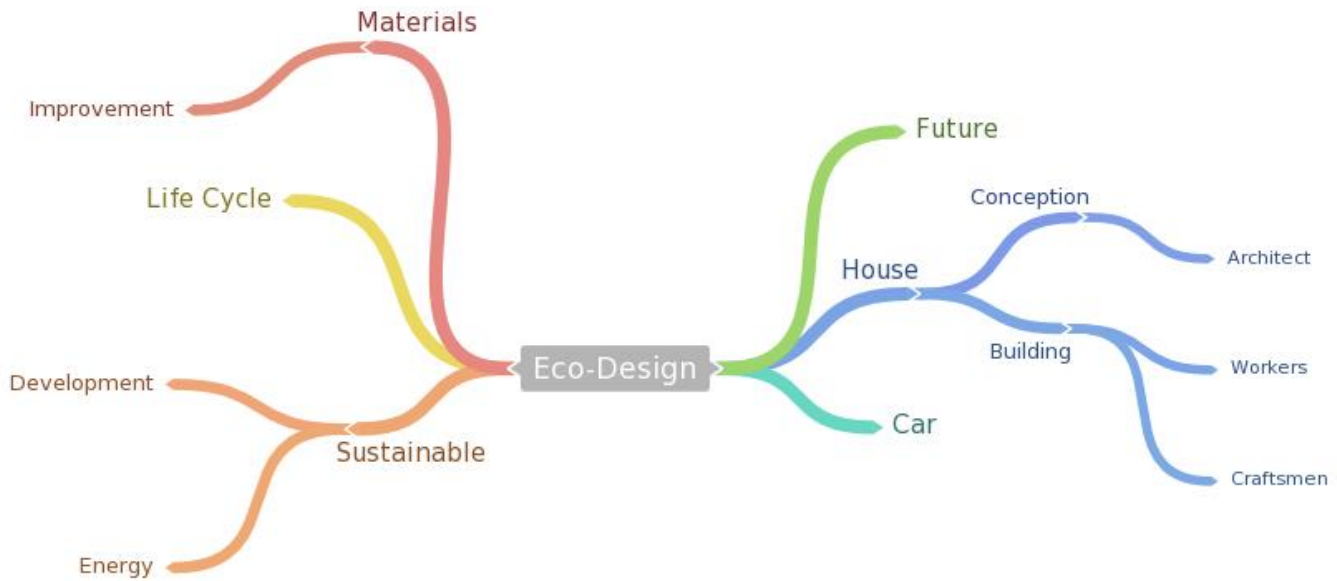
## Appendix : Opeduca Mind Maps for France

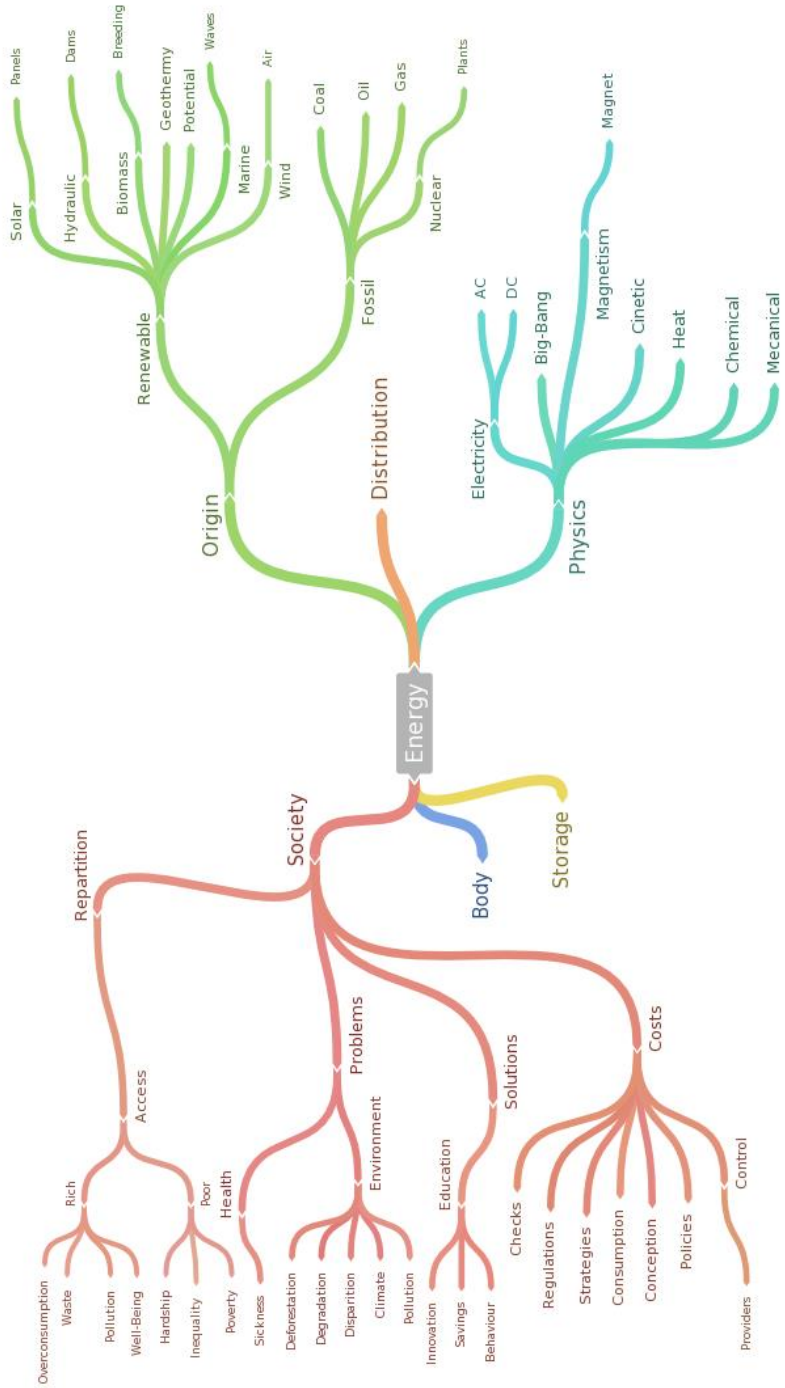
Each of the following mind maps *synthesize* several mind maps about Food, Energy, Eco-Design, and Water, drawn by pupils from *Lycée Lesage* secondary school (Vannes, France) with the help of their teachers. They were made using *Coggle* (https://coggle.it/).


Food
distribution
costs
retail
transportation
politics
big
small
middle sized
quotas
production
places
optimization
new
new
means
ressources
agriculture
fishing
breeding
repartition
access
rich countries
abundance
poor countries
deficiencies
inequalities
uses
imperative
hygiene
restauration
daily
transportation
health
equilibrium
growth
vitamines
alimentation
animal
meat
fish
eggs
milk
salt
mineral
vegetal
sugar
vegetables
fruits
cereal
problems
globalization
overconsuming
overexploitation
waste
preservative
enhancer
pollution
obesity
sicknesses
solutions
education
favor
production
meals
local
balanced
respect
do not waste

coggle


Water
Problems
Ethics
Free
Appropriation
Climate
Warming
Availability
Repartition
Poor
Pollution
Shortages
Rich
Available
Running
Countries
Threats
Pollution
Waste
Solutions
Education
Save
Manage
Restore
Protect
Marketing
Quantity
Network
Collectivities
Costs
Bills
Service
Public
Cleansing
Distribution
Packaging
Storage
Transport
Treatment
Waste
Origin
Ressources
Atmospheric
Hydric
Physics
Oxygen
Hydrogen
Uses
Imperative
Hygiene
Industry
Domestic
Health
Savings
Indvidual
Collective


Materials
Improvement
Life Cycle
Development
Sustainable
Energy
Eco-Design
Future
House
Conception
Architect
Building
Workers
Craftsmen
Car


Energy
Origin
Renewable
Solar
Panels
Hydraulic
Dams
Biomass
Breeding
Geothermy
Potential
Waves
Marine
Air
Wind
Fossil
Coal
Oil
Gas
Nuclear
Plants
Distribution
Physics
Electricity
AC
DC
Big-Bang
Magnetism
Magnet
Cinetic
Heat
Chemical
Mecanical
Body
Storage
Society
Repartition
Access
Rich
Poor
Overconsumption
Waste
Pollution
Well-Being
Hardship
Inequality
Poverty
Health
Sickness
Problems
Environment
Deforestation
Degradation
Disparition
Climate
Pollution
Solutions
Education
Innovation
Savings
Behaviour
Costs
Checks
Regulations
Strategies
Consumption
Conception
Policies
Control
Providers